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The Effects of Vehicular Induced Motion on Target Acquisition and Tracking Performance Using a Fixed Yoke With Thumb-Operated Tracking Control Versus a Conventional Displacement Yoke

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Abstract

This report describes a study designed to quantify the effects of vehicular induced motion on tank gunner performance using two different control handles. One control was a fixed yoke that incorporated a thumb-operated tracking button. The second control was a more conventional displacement yoke which functioned like that in the current M1A1 tank. The study was conducted on a ride motion simulator which had been programmed to impart four levels of ride motion. These ride levels were derived from a simulation of the M1 tank traveling over various test courses at Aberdeen Proving Ground, Maryland. Generally, as vertical acceleration increased, performance decreased for both controls, but the vertical accelerations imparted to the gunners at the more severe ride levels effected a greater reduction in time on target using the thumb button than they did when using the displacement yoke. Performance using the thumb button was more affected by target motion.

ACKNOWLEDGMENTS

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We are particularly grateful to all the armor crewmen who participated in this study and to Mira Filipovski (Program Manager's Office - Crewman's Associate) and SFC Ron Quinn (Directorate of Combat Development - Fort Knox, KY) who assisted in the scheduling of these soldiers and the many other details of this investigation.

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EXECUTIVE SUMMARY

This report describes a study conducted by the Human Research and Engineering Directorate of the U.S. Army Research Laboratory in support of the Program Manager-Crewman's Associate. The purpose of the investigation was to measure and compare target acquisition and tracking performance using two prototype, multi-function control handles in the motion environment to which an armored combat vehicle and its crew would be exposed.

One of the control handles assessed was a fixed yoke that incorporated a thumb-operated, isometric tracking button on the right handgrip. The second control handle was a displacement yoke similar to the conventional Cadillac Gage[1] control in the M1A1 tank. The prototype yoke had been programmed with the same response characteristics as the "Cadillac," and movement of the gunner's reticle was effected in a similar manner by rotating the handgrips up and down and from side to side. Both the fixed yoke with thumb button and the displacement yoke incorporated triggers on the left and right handgrips.

The study was conducted on a ride motion simulator (RMS) which had been programmed to impart four levels of ride motion ranging from "mild" to "severe." These ride levels were derived from a simulation of the M1 tank traveling over various test courses at Aberdeen Proving Ground, Maryland.

The 30 combat vehicle crewmen who participated in the study were randomly assigned to one of two groups. One group of 15 crewmen performed target acquisition and tracking tasks using the fixed yoke with the thumb button, and the other group of 15 crewmen performed the same tasks using the displacement yoke. Each subject was first trained to the point at which he achieved an asymptote and then performed two test runs in the stationary or no-motion condition before training and testing with motion. During training with motion, the subjects completed consecutive runs at a ride level that represented a midpoint in ride severity between Ride Level 1 and Ride Level 4. When the subjects again attained an asymptote in performance at this ride level, they completed two runs at each of the four levels of ride motion.

The duration of each run in both the stationary and ride motion condition was 2 minutes. For each level of ride motion, the same 60-second ride was repeated twice during the 2-minute period. During the first minute of each run, the crewmen performed the target acquisition task in which a total of six stationary targets were presented. Upon the presentation of each target, the

[1]name of company

crewman slewed his reticle onto the target as rapidly and accurately as possible and depressed the firing trigger. Time to target was based on the time at which the target was presented to the time the trigger was depressed. Lay error at trigger pull was also measured. The average vertical acceleration, frequency, and absorbed power of the ride were computed from the time the target was presented until the time of trigger pull.

During the second minute of each run, subjects performed the target tracking task. During this period, three targets were presented one at a time. One of these targets remained stationary, the other took a straight line path to the right and then to the left in the display (or vice versa), and the third moved evasively in a sine wave-like maneuver. Upon the presentation of each target, the crewman slewed his reticle onto the target as rapidly and accurately as possible and depressed the firing trigger. The subject was required to maintain his crosshairs on the target and pull the trigger as often as he was assured that his crosshairs were on that target. Average lay error at trigger pull, time on target, and the percent of hits to the total number of trigger pulls were computed for each of the three targets. The average vertical acceleration, frequency, and absorbed power of the ride were computed from the time the target was presented to the time of the last trigger pull.

The analyses of covariance (ANCOVA) that were performed on the target acquisition and tracking data did not reveal any statistically significant main effects between the two controls. However, significant interactions were found between target and control where additional analyses revealed that subjects using the thumb button achieved less time on moving targets ($p < .05$) along with a lower percentage of hits on evasive targets ($p < .05$) than did subjects using the displacement yoke.

Generally, as vertical acceleration increased, performance decreased for both controls, but further analyses revealed that the vertical accelerations imparted to the gunners at Ride Levels 2, 3, and 4 effected a greater reduction in time on target using the thumb button than they did when using the displacement yoke ($p < .05$). Similarly, the vertical accelerations at Ride Levels 2 and 4 had a greater impact on lay error using the thumb button, as did the vertical accelerations at Ride Level 4 on percent hits.

The effects of target motion and vertical acceleration on tracking performance using the thumb button are primarily attributed to control sensitivity and inadvertent input to the thumb button during movement of the fingers on the same hand used to operate this control.

THE EFFECTS OF VEHICULAR INDUCED MOTION ON TARGET ACQUISITION AND TRACKING PERFORMANCE USING A FIXED YOKE WITH THUMB-OPERATED TRACKING CONTROL VERSUS A CONVENTIONAL DISPLACEMENT YOKE

INTRODUCTION

The objective of the Crewman's Associate Advanced Technology Demonstration (CA ATD) program is to demonstrate enhancements in crew performance through the application of advanced technologies as near-term product improvements of the current M1A2 tank and ultimately as an integrated crew station for future combat vehicle systems. Through improvements in control-display design and their interface with the soldier, the program seeks to develop a crew station that ensures a reduced crew can fight as effectively as a four-man crew. At the request of the program manager (Crewman's Associate), the Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory (ARL) conducted a study to measure and compare the effects of vehicular induced motion on gunner performance using two prototype, multi-function control handles. One control handle was a fixed yoke which incorporated a thumb-operated isometric button; the other control was a displacement yoke similar to that currently in the M1A1 tank.

Previous research conducted on a ride motion simulator (RMS) at the Tank-Automotive Research Development & Engineering Center (TARDEC) has compared gunner performance using the conventional displacement yoke with that using a thumb button incorporated on a fixed joystick (Lee, West, & Glumm, 1980). Generally, the results indicated that as the severity of the ride increased, gunner performance decreased and that the magnitude of the degradation in performance varied between control configurations. Differences in performance between the displacement yoke and the thumb button were attributed in part to inadvertent input to the thumb button at trigger pull. Glumm, Singapore, and Lee (1983) found an even greater difference between the displacement yoke and the thumb button when subjects operated these controls while wearing chemical protective gloves. In this latter study, degradations in performance with the thumb control were primarily attributed to the bulk of the chemical protective glove and the difficulty in sensing and thus controlling the force applied to the thumb button.

In another study conducted on the same ride motion simulator, performance using the conventional displacement yoke was compared with that using a displacement joystick (Sharkey, Schwirzke, McCauley, Casper, & Hennessy, 1995). Generally, tracking performance using the displacement yoke was better than that using the displacement joystick. In this study, it was also found that experienced armor crewmen tracked with greater accuracy using the yoke than

they did using the joystick, whereas the opposite was true for the civilian participants. This finding was attributed to strategies that the armor crewmen may have learned that allowed them to more effectively limit the feed-through of motion from their seat to the displacement controls.

In the present study, it was believed that the additional body stability offered by the fixed yoke that incorporated the thumb button and the opportunity to trigger from the left handgrip would reduce inadvertent control input and thus close the gap in performance between it and the more conventional displacement yoke.

OBJECTIVE

The purpose of this experiment was to measure and compare the effects of vehicular induced motion on target acquisition and tracking performance using a fixed yoke that incorporated a thumb-operated isometric button with the effects using a more conventional, displacement yoke.

METHOD

Subjects

The 30 combat vehicle crewmen who participated in this study were randomly assigned to one of two groups. One group of 15 crewmen (Group A) performed the target acquisition and tracking tasks using a fixed yoke that incorporated a thumb-operated, isometric tracking control, and the other group of 15 crewmen (Group B) performed the same tasks using a displacement yoke. During training and testing, all subjects wore the standard Nomex gloves.

The average age of the crewmen in both groups was approximately 34 years, and differences between Groups A and B in average time in service (14.9 versus 14.5 years), time in grade (3.6 versus 3.4 years), and time in MOS (12.8 versus 11.2 years) were small. The military occupational specialty (MOS) of all but three of the 15 crewmen in each of the two groups was armor crewman (19K). All the subjects had fired the main gun of the M1 tank while moving and had qualified in Level I gunnery. Except for four crewmen in Group B, all subjects were right handed. All subjects met the visual acuity requirements for 20/20 in one eye and at least 20/100 in the other eye, corrected or uncorrected.

Apparatus

Ride Motion Simulator (RMS)

The study was conducted on the RMS at the U.S. Army Tank-Automotive and Armaments Command (TACOM) in Warren, Michigan. The RMS is a hydro-pneumatically actuated simulator capable of providing the vertical, pitch, roll, and yaw motion of a tracked vehicle. The simulator accommodates one individual in an upright seated position, restrained by a seat belt (see Figure 1). For this study, the RMS was programmed to simulate rides imparted to the gunner in an M1 tank traveling at various speeds over test courses at Aberdeen Proving Ground, Maryland. Four levels of ride were programmed ranging from "mild" (Ride Level 1) to "severe" (Ride Level 4). The average vertical accelerations imparted to the gunners during these rides ranged from 0.05 g root mean square (rms) at the milder ride (Ride Level 1) to 0.25 g rms at the more severe ride (Ride Level 4). The average frequency of the two mildest rides (i.e., Ride Levels 1 and 2) was 1.3 Hz. The average frequencies at the two more severe rides (i.e., Ride Levels 3 and 4) were 0.7 Hz and 1.0 Hz, respectively. These four levels of ride and the ride level used for training are described in Table 1. A more detailed description of the simulation ride levels is provided by Lebioda, Hoist, and Zywiol (1995).

Controls

The two controls assessed during this study included a fixed, multi-function yoke developed by Lear (see Figure 2) and a more conventional, displacement yoke developed by Texas Instruments (see Figure 3). The fixed yoke incorporated a thumb-operated, isometric button on the right handgrip. This thumb button was used to control the movement of the gunner's reticle. The displacement yoke, called the electronic systems integration (ESI) handle, had been programmed with the same response characteristics as those of the conventional Cadillac Gage[2] control in the M1A1 tank, and movement of the gunner's reticle was effected in a similar manner by rotating the handgrips up and down and from side to side. Both the fixed yoke with thumb button and the displacement yoke incorporated firing triggers on the left and right handgrips. During training with the fixed yoke with thumb button, most subjects noted that they would inadvertently apply force to the thumb button when triggering from the same handgrip. All opted to trigger from the opposite handgrip.

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[2]Name of company

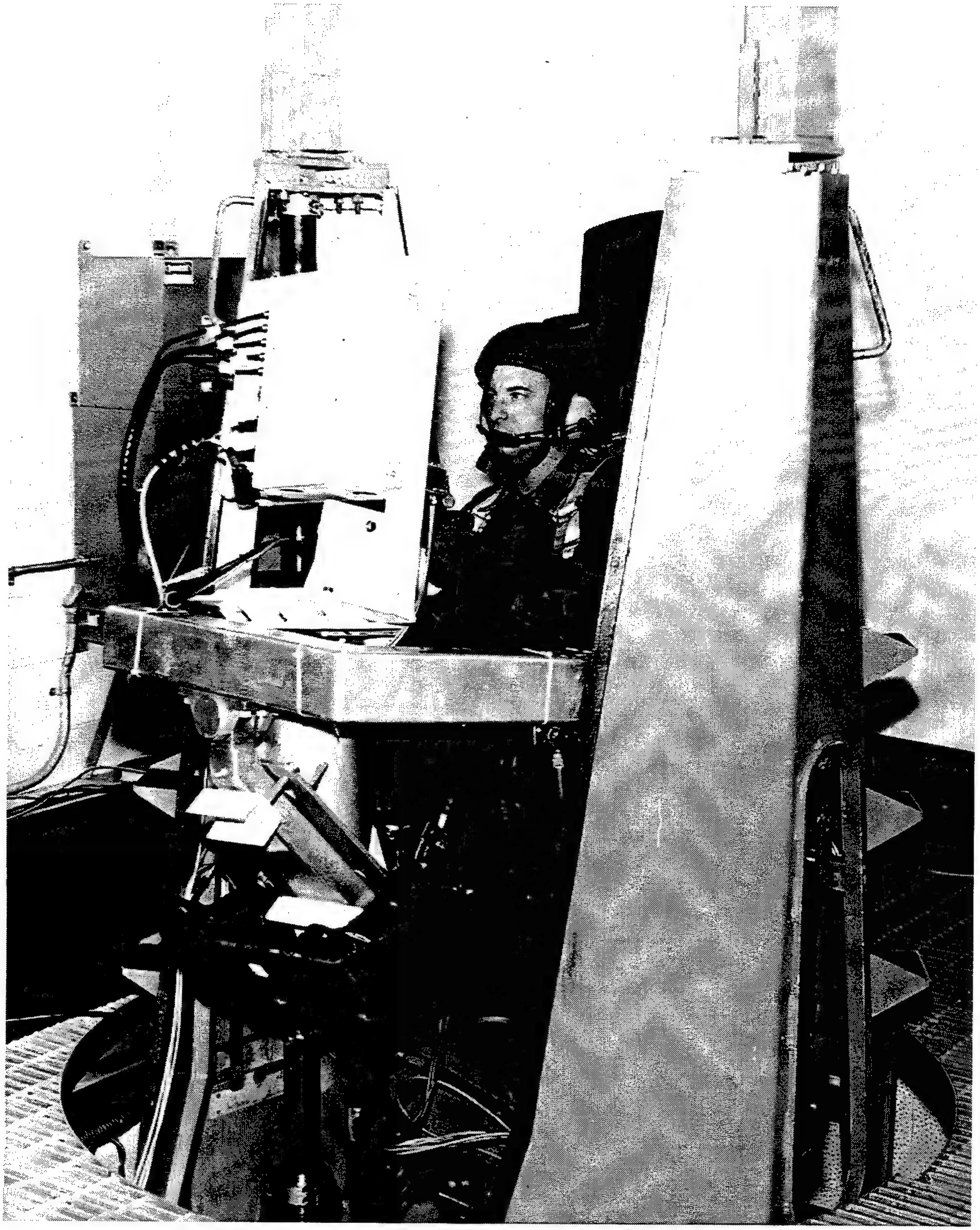


Figure 1. Ride motion simulator.

Table 1

Ride Level Description

Ride level	Terrain*	Vertical acceleration (g)	Frequency (Hz)	Absorbed power (watt)
		(average values for all test runs)		
0	N/A	0	0	0
1	Perryman A @ 40 mph	0.05	1.3	0.1
2	Perryman 3 @ 10 mph	0.10	1.3	0.5
Training	Letourneau 6 @ 10 mph	0.10	1.3	0.7
3	Churchville B @ 12 mph	0.13	0.7	1.2
4	Perryman 2 @ 23 mph	0.25	1.0	2.8

*All courses located at Aberdeen Proving Ground, Maryland, except the training ride (Letourneau) which is located at Waterways Experiment Station (WES) in Vicksburg, Mississippi.

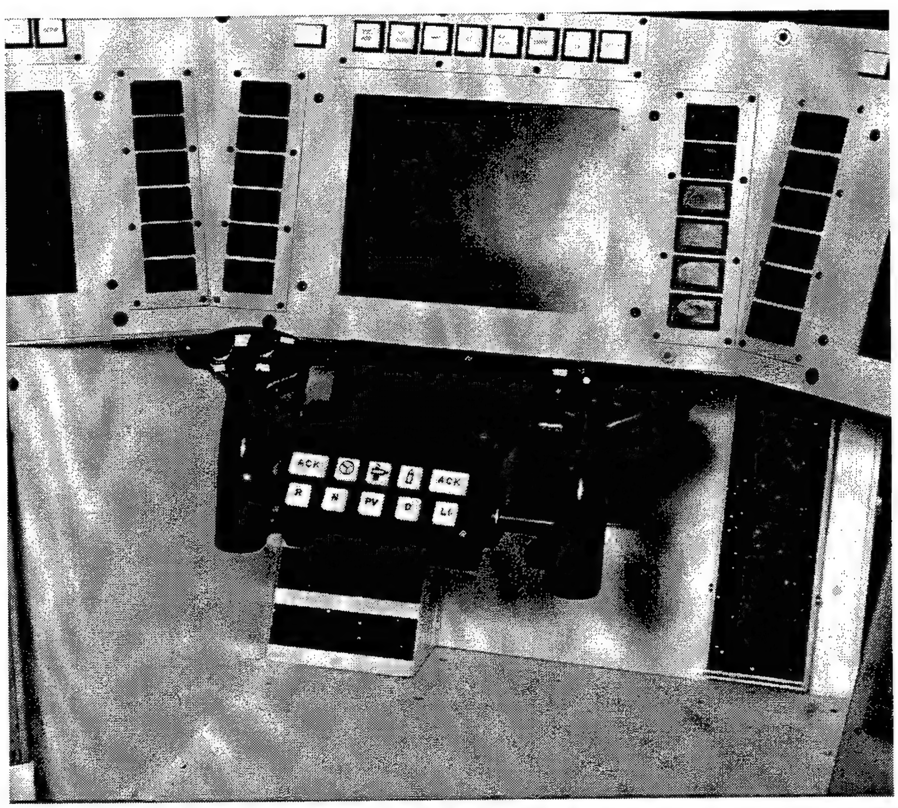


Figure 2. The fixed yoke with thumb-operated, isometric button.

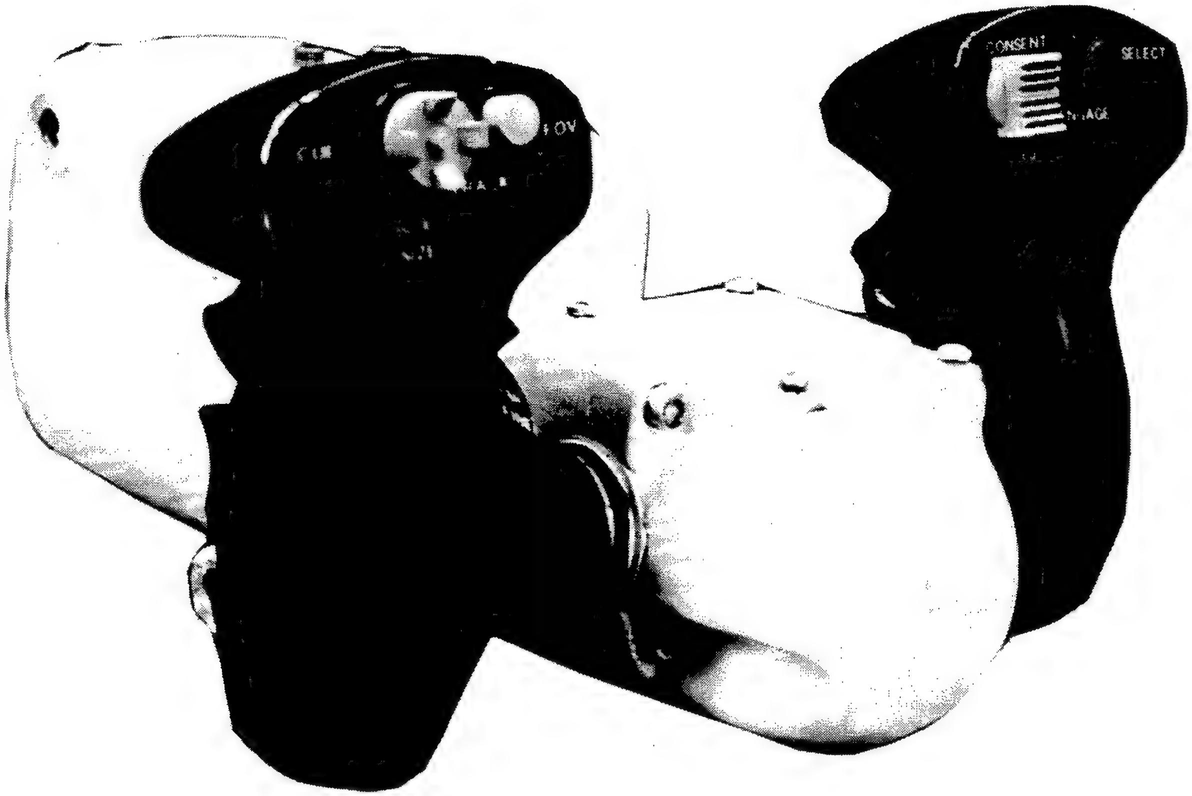


Figure 3. The displacement yoke.

Display

During the study, the subjects acquired and tracked targets that were presented on a flat panel, liquid crystal display (LCD). The size of the display was 15.2 by 22.9 cm (6 by 9 inches) with a resolution of 640 by 480 lines.

Targets

The targets that were presented on the LCD were black, displayed on a white background. All were 5.5 mm square in size which subtends the same visual angle of an M1 tank (3.6 milliradians, side view, gun forward) at 2500 m as seen through an M1 3X (wide field of view) daysight (10.8 milliradians at the nominal 20-inch viewing distance). All moving targets moved at the same constant velocity, equivalent to 58 kph (36 mph).

Procedures

Subject Screening and Pre-Test Questionnaires

A visual acuity test, at far and near distances, was administered to each of the 30 volunteers to ensure 20/20 vision in one eye and at least 20/100 in the other eye (corrected or uncorrected). All subjects completed a questionnaire to obtain pertinent demographic and background information (see Appendix A) and received instruction in the completion of a motion sickness questionnaire (see Appendix B). This latter questionnaire was administered before, during, and after training and testing to monitor for the possible onset of this syndrome.

Training and Test

Fifteen (15) of the 30 subjects who participated in this investigation were trained to perform the target acquisition and tracking tasks with the fixed yoke control and the other 15 subjects were trained to perform the same tasks with the displacement yoke.

For each control, training and testing was first completed in the stationary or "0" ride level condition before training and testing in the four levels of ride motion. After instruction and practice in performing the target acquisition and target tracking tasks, the subject performed these tasks during consecutive runs until he had attained an asymptote in time to target in the target acquisition task and time on target in the target tracking task. An asymptote was determined using the moving average technique. The subject then performed two test runs in the "0" ride level condition. After each of these test runs, the subject completed a questionnaire pertaining to his experience during that run using the given control type.

After completion of training and testing in the stationary condition, the subject then became familiar with performing the target acquisition and tracking tasks during one run at each of the four levels of ride motion, starting with the mildest ride (Ride Level 1) and graduating to the most severe ride (Ride Level 4). The subject then completed consecutive runs at a ride level that represented a midpoint in average watts absorbed power between Ride Levels 1 and 4 until he reached an asymptote in time to target in the target acquisition task and time on target in the target tracking task.

During testing, the subject completed two runs at each of the four levels of ride motion for a total of 8 runs. The order of presentation of Ride Levels 1 through 4 were counterbalanced as shown in Table 2. For each control type, after each of the eight test runs, the

subject completed a questionnaire to obtain information pertaining to his experience using a given control handle at that level of ride motion to which he had just been exposed (see Appendix C).

Table 2

Counterbalancing Scheme

Control A	Control B	Iteration 1	Iteration 2
Subjects		Ride Levels	
1	16	4 2 3 1	1 2 4 3
2	17	2 3 4 1	4 3 2 1
3	18	2 1 4 3	1 4 2 3
4	19	3 2 1 4	2 1 3 4
5	20	3 1 2 4	3 2 4 1
6	21	1 3 2 4	4 3 1 2
7	22	4 2 1 3	2 3 1 4
8	23	2 4 3 1	3 4 2 1
9	24	1 3 4 2	1 2 3 4
10	25	4 1 2 3	4 1 3 2
11	26	1 4 3 2	2 4 1 3
12	27	3 4 1 2	3 1 4 2
13	28	1 4 2 3	3 1 2 4
14	29	2 1 3 4	1 4 3 2
15	30	3 2 4 1	2 3 4 1

Target Acquisition and Tracking Tasks

The duration of each run at each ride level was 2 minutes in which the same 60-second ride was repeated twice. During the first minute of each run, the subjects performed the target acquisition task. During this period, a total of six stationary targets were presented. One target was presented every 10 seconds and displayed for a duration of 8 seconds. The targets appeared at the same times into each run, but the locations at which these targets appeared on the display were randomized within and between runs. Upon the presentation of each target, the crewman slewed his reticle onto the target as rapidly and accurately as possible and depressed the firing trigger. Upon depression of the trigger, the target disappeared from the screen. The target also disappeared from the screen if it had not been fired upon within an

8-second period. In this latter instance, the target was scored as a miss and flagged. Time to acquire the target was based on the time from target presentation to the time of trigger pull. Lay error (rms) at trigger pull was also measured. For the target acquisition task, an average frequency, vertical acceleration, and absorbed power were computed from the time the target was presented to the time of trigger pull.

During the second minute in each run, subjects performed the target tracking task. During this period, three targets were presented one at a time. One of these targets remained stationary, the other took a straight line path to the right and then to the left in the display (or vice versa), and the third moved evasively in a sine wave-like maneuver (see Figure 4). All moving targets moved at a constant velocity. The targets were the same size as those presented during the target acquisition task. Each of these targets was presented for a duration of approximately 15 seconds. The location at which these targets appeared on the crewman's display and the type of movement they made (i.e., stationary, straight line, or evasive) was randomized among runs. Upon the presentation of each target, the crewman slewed his reticle onto the target as rapidly and accurately as possible and depressed the firing trigger. The subject was required to maintain his crosshairs on the target and pull the trigger as often as he was assured that his crosshairs were on that target. Average lay error (rms) at trigger pull, time on target, and the percent of hits to the total number of trigger pulls were computed for each of the three targets. For each target, the average vertical acceleration, frequency, and absorbed power were computed from the time the target was presented to the time of the last trigger pull.

The design matrix for this experiment is shown in Figure 5. The study was a repeated measures design with control type as a between-subjects variable. The two control types were the fixed yoke with thumb button and the displacement yoke. Target motion was a within-subjects variable in the target tracking task only. The three target motions included stationary, straight line, and evasive.

In the analysis of target acquisition performance, the dependent variables were time from target presentation to trigger pull and lay error at trigger pull. The dependent variables in the analysis of target tracking performance were time on target, lay error at trigger pull, and the percent hits to the total number of trigger pulls. Because absorbed power is a function of vertical acceleration and frequency, only the latter two vibration characteristics of the ride were used as covariates in the analyses.

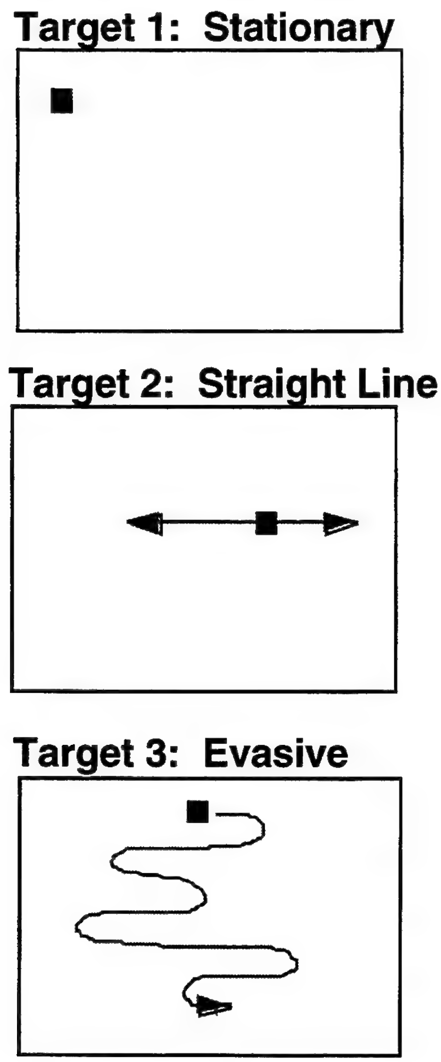


Figure 4. Targets.

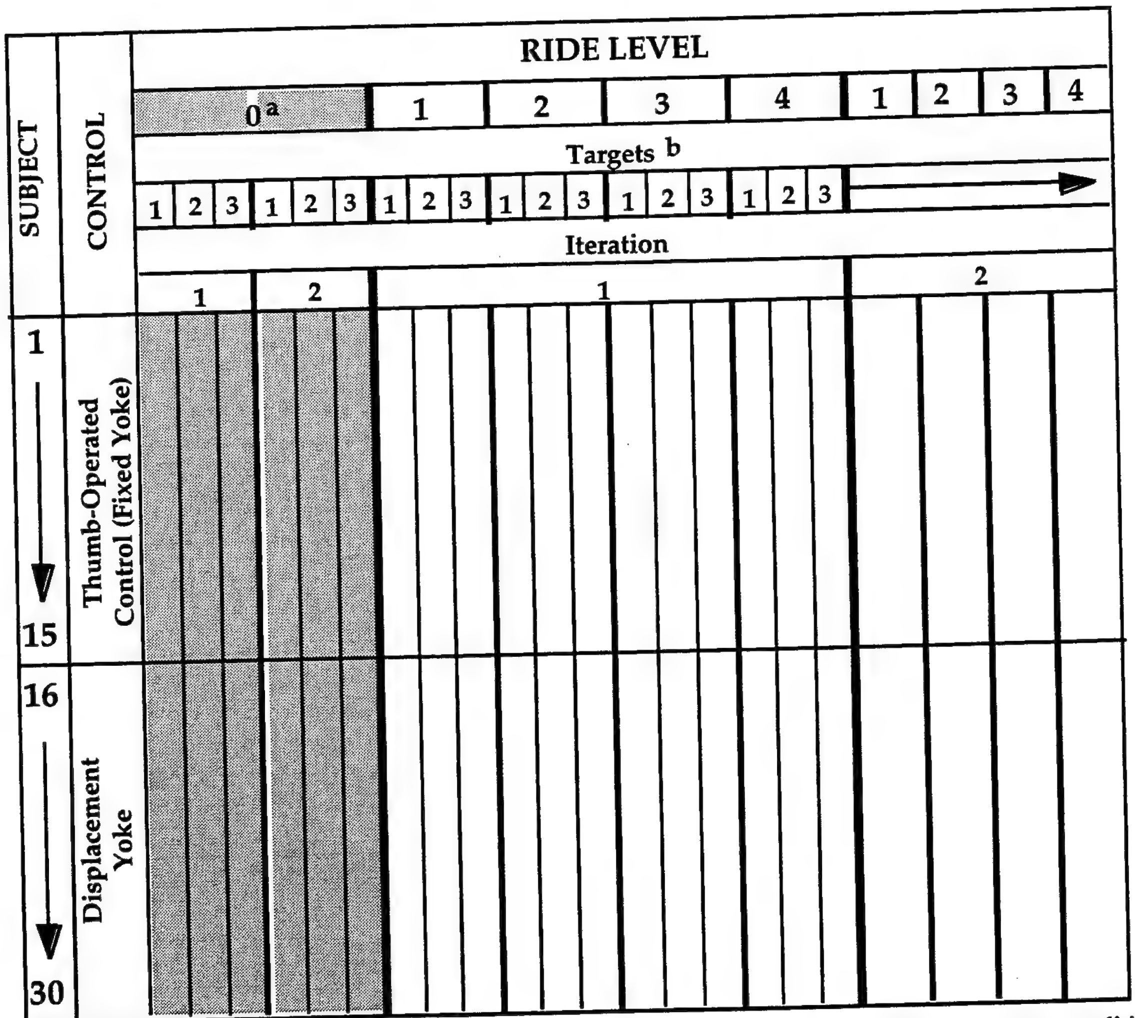
RESULTS

Target Acquisition

Time to Target

The mean time from target presentation to trigger pull was subjected to an analysis of covariance (ANCOVA) with control type (the fixed yoke with thumb button versus the displacement yoke) as a between-subjects effect. Average vertical acceleration and frequency, as recorded from the time the target was presented to the time of trigger pull, were used as covariates in this analysis. As shown in Table 3, no statistically significant main effects were found between the two controls on this measure of performance. The results, however, did indicate a positive relationship ($r = 2.28$) between target acquisition time and vertical acceleration,

t = 13.10, $p < .000$. This finding indicates that as vertical acceleration increased, the time to acquire the target also increased. A negative relationship (r = -0.025) was found between target acquisition time and frequency, t = -8.09, $p < .000$. This finding reflects the lower frequencies at the more severe ride levels where vertical accelerations were greatest and performance of this task the poorest.



[a]Subjects were trained and tested in the "0" ride level condition before training and testing in motion conditions.
[b]Target motion was a within-subjects variable in the target tracking task only.

Figure 5. Design matrix.

Table 3

Target Aquisition: Results of ANCOVA of Time to Target

	SS	df	MS	F	*p*
Controller	.001	1	.001	.001	.98
Subject within controller	558.840	30	18.630		

Covariates

	Coefficients	B (standardized coefficients)	Std error	T	*p*
Vertical acceleration	2.280	.295	.174		
Frequency	- 0.256	- .175	.032	- 8.09	.000

Means (seconds)

	Thumb button	Displacement yoke
Controller	3.57	3.22

Lay Error

Mean lay error in millimeters (rms) was also subjected to an ANCOVA with control type as a between-subjects effect. Average vertical acceleration and frequency, as recorded from the time the target was presented to the time of trigger pull, were used as covariates in this analysis. As shown in Table 4, no statistically significant main effects were found between the two controls. However, a positive relationship (r = 10.90) was found between lay error and vertical acceleration, $t = 5.70$, $p < .000$. This finding indicates that as vertical acceleration increased, lay error at trigger pull also increased. A negative relationship (r = -0.76) was found between lay error and frequency, $t = -2.18$, $p < .03$. This effect is attributed to the lower frequencies at the more severe ride levels where vertical accelerations were greatest and performance on this measure lowest.

Table 4

Target Acquisition: Results of ANCOVA of Lay Error[a]

	SS	df	MS	F	*p*
Controller	.001	1	.001	.001	.99
Subject within controller	1757.400	29	60.600		
Target	4.940	2	3.680	.550	.56
Target x Controller	17.720	2	5.080	.750	.48
Target x Subject within controller	377.640	56	6.740		

Covariates

	Coefficients	B (standardized coefficients)	Std error	T	*p*
Vertical acceleration	7.580	0.286	0.822	9.220	.000
Frequency	0.001	0.001	0.182	- 0 .003	.998

Means and standard deviations (*)
in millimeters-rms and [milliradians-rms]

Controller	Thumb button	Displacement yoke	
	6.43 [4.22]	5.32 [3.49]	
	(2.9)* [1.90]*	(2.7)* [1.80]*	
Target	Stationary	Straight line	Evasive
	5.37 [3.52]	5.85 [3.84]	6.38 [4.19]
	(2.33)* [1.53]*	(3.32)* [2.18]*	(2.77)* [1.82]*

[a]The ANCOVA was performed on lay error computed with respect to the gunner's display (3X daysight) in millimeters. Means for lay error are also provided in milliradians to represent the gun tube angle with respect to the distant target.

Target Tracking

Time on Target

The mean time on target was subjected to an ANCOVA with control type as a between-subjects effect and target motion as a within-subjects effect. Average vertical acceleration and frequency, as recorded from the time of target presentation to the time of the last trigger pull on each of the three targets (i.e., stationary, straight line, and evasive), were used as

covariates in this analysis. As in the target acquisition task, no statistically significant main effects were found between the two controls (see Table 5). However, a significant interaction was found between target and control, F (2, 56) = 5.48, $p < .006$, with mean times on stationary, straight line, and evasive targets of 10.79 seconds, 9.89 seconds, and 9.57 seconds, respectively, using the thumb button, and mean times on these targets of 10.82 seconds, 11.12 seconds, and 11.09 seconds, respectively, using the displacement yoke. The results of a Scheffé analysis indicated that this interaction was attributable, in part, to the significant difference between mean times on stationary and evasive targets using the thumb button ($X_{diff} \pm 1.22, p < .05$), by comparison to the displacement yoke, where no differences were found (see Figure 6). Most importantly, the analysis also revealed that subjects using the displacement yoke achieved longer times on both straight line and evasive targets than those subjects who used the thumb button ($X_{diff} \pm 1.52, p < .05$).

As shown in Table 5, the results of the ANCOVA also indicated a negative relationship (r = -5.64) between time on target and vertical acceleration, t = -8.04, $p < .000$. This finding indicates that as vertical acceleration increased, time on target decreased. Additional analyses were performed to determine if this relationship between vertical acceleration and performance was consistent for both controls. The results of these analyses indicated that the vertical accelerations imparted to the gunners at Ride Levels 2, 3, and 4 (see Figure 7) had a greater impact on time on target using the thumb button than they did on time on target using the displacement yoke ($X_{diff} \pm .90, p < .05$).

Lay Error

The mean lay error in millimeters (rms) at trigger pull was subjected to an ANCOVA with control type as a between-subjects effect, and target motion as a within-subjects effect. Average vertical acceleration and frequency, as recorded from the time of target presentation to the time of the last trigger pull on each of the three targets (i.e., stationary, straight line, and evasive), were used as covariates in this analysis. Again, no statistically significant main effects were found between controls (see Table 6). A positive relationship (r = 7.58) was found between vertical acceleration and lay error, t = 9.22, $p < .000$. This finding indicates that as vertical acceleration increased, error also increased. Additional analyses were performed to determine if this relationship between vertical acceleration and performance was consistent for both controls. The results of these analyses indicated that the vertical accelerations imparted to the gunners at Ride Levels 2 and 4 (see Figure 8) had a greater impact on lay error using the thumb button than they did on lay error using the displacement yoke ($X_{diff} \pm .01, p < .05$).

Table 5

Target Tracking: Results of ANCOVA of Time on Target

	SS	df	MS	F	*p*
Controller	0.01	1	0.01	0.001	0.990
Subject within controller	1752.80	29	60.44		
Target	36.96	2	18.48	2.340	0.110
Target x Controller	86.32	2	43.16	5.480	0.006
Target x Subject within controller	441.32	56	7.88		

Covariates

	Coefficients	B (standardized coefficients)	Std error	T	*p*
Vertical acceleration	- 5.640	- 0.248	0.202	- 8.04	.000
Frequency	- 0.088	- 0.018	0.153	- 0.57	.569

Means (seconds)

Controller	Thumb button	Displacement yoke	
	10.07	11.01	
	(2.69)*	(2.13)*	
Target	**Stationary**	**Straight line**	**Evasive**
	10.81	10.51	10.31
	(2.74)*	(2.42)*	(2.22)*
Target	**Stationary**	**Straight line**	**Evasive**
Controller (thumb button)	10.79	9.89	9.57
Controller (displacement yoke)	10.82	11.12	11.09

*Standard deviations

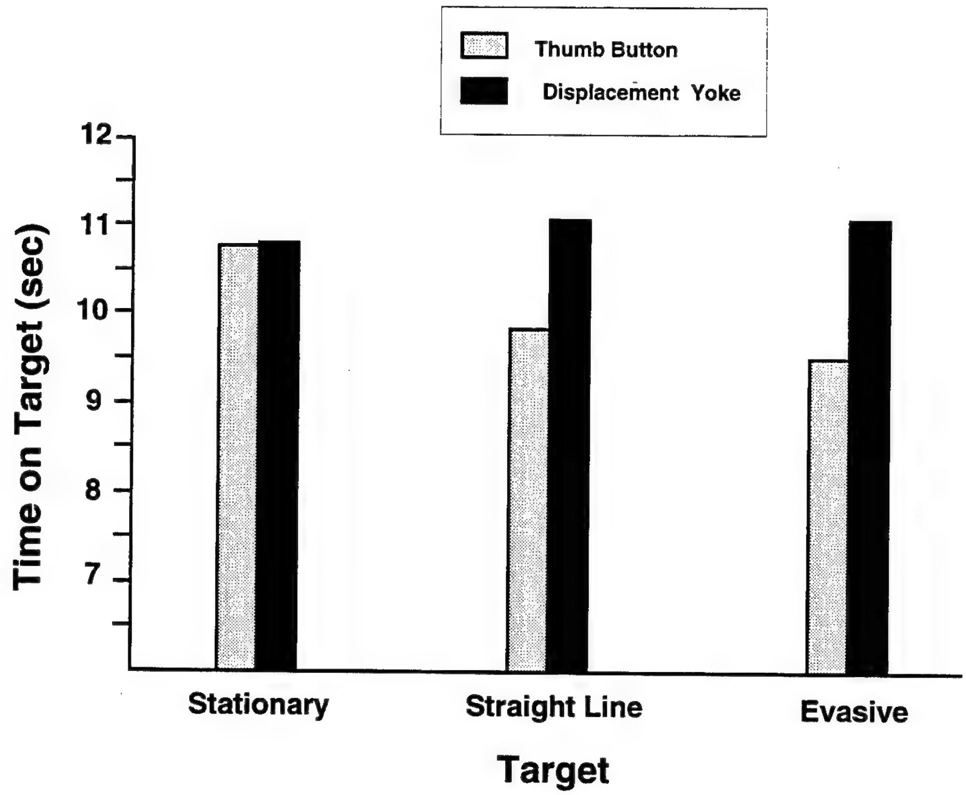


Figure 6. Mean time on target by target.

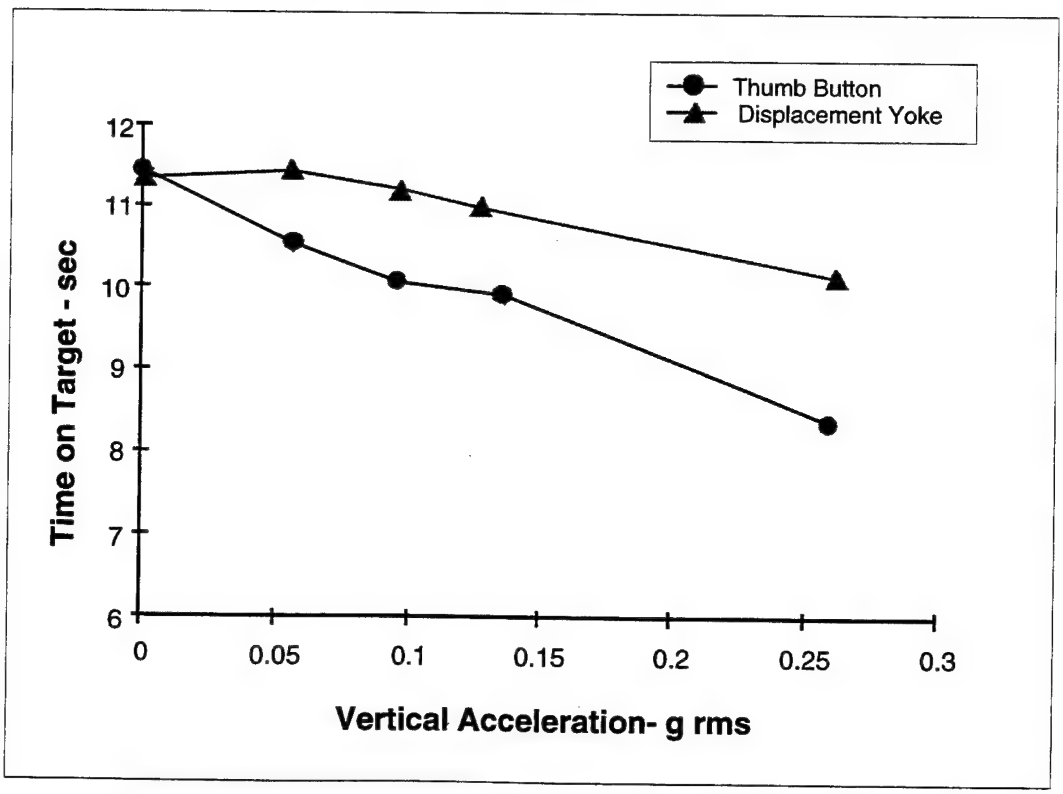


Figure 7. Mean time on target by average vertical acceleration.

Table 6

Target Tracking: Results of ANCOVA of Lay Error[a]

	SS	df	MS	F	*p*
Controller	.001	1	.001	.001	.99
Subject within controller	1757.400	29	60.600		
Target	4.940	2	3.680	.550	.56
Target x Controller	17.720	2	5.080	.750	.48
Target x Subject within controller	377.640	56	6.740		

Covariates

	Coefficients	B (standardized coefficients)	Std error	T	*p*
Vertical acceleration	7.580	0.286	0.822	9.220	.000
Frequency	0.001	0.001	0.182	- 0.003	.998

Means and standard deviations (*)
in millimeters-rms and [milliradians-rms]

Controller	Thumb button 6.43 [4.22] (2.9)* [1.90]*	Displacement yoke 5.32 [3.49] (2.7)* [1.80]*	
Target	Stationary 5.37 [3.52] (2.33)* [1.53]*	Straight line 5.85 [3.84] (3.32)* [2.18]*	Evasive 6.38 [4.19] (2.77)* [1.82]*

[a]The ANCOVA was performed on lay error computed with respect to the gunner's display (3X daysight) in millimeters. Means and standard deviations for lay error are also provided in milliradians to represent the gun tube angle with respect to the distant target.

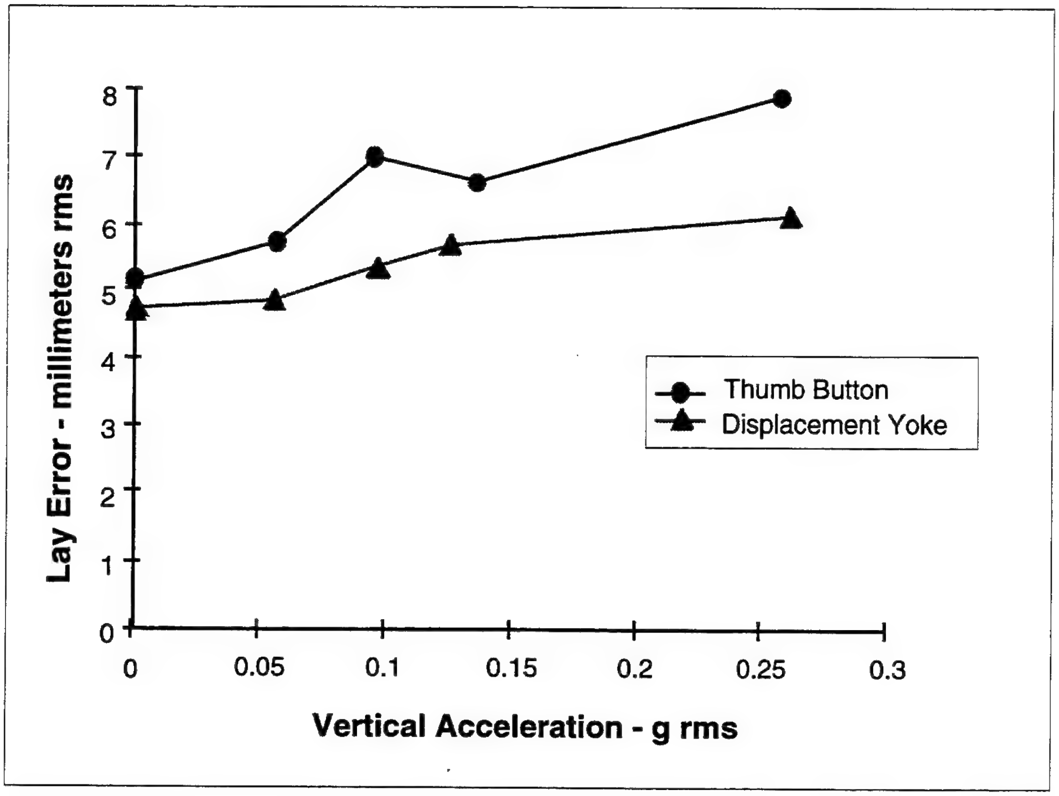


Figure 8. Mean lay error by average vertical acceleration.

Percent Hits

The mean percent hits of the total number of trigger pulls was also subjected to an ANCOVA with control type as a between-subjects effect and target motion as a within-subjects effect. Average vertical acceleration and frequency, as recorded from the time of target presentation to the time of the last trigger pull on each of the three targets (i.e., stationary, straight line, and evasive), were used as covariates in this analysis. Once again, as shown in Table 7, no statistically significant main effects were found between the two controls. However, a significant main effect was found for target, $F(2, 56) = 5.50, p < .001$, with mean percent hits of 95%, 93%, and 92% on stationary, straight line, and evasive targets, respectively. The main effect for target is attributed to the significant decrease in percent hits between stationary and evasive targets ($X_{diff} \pm .03, p < .05$). Of particular importance is the interaction that was found between target and control, $F(2, 56) = 5.00, p < .003$, with mean percent hits on stationary, straight line, and evasive targets of 96%, 91%, and 88%, respectively, using the thumb button, and 95%, 95%, and 96%, respectively, using the displacement yoke. This interaction is attributed, in part, to the significant reduction in the mean percent hits found between stationary and evasive targets using the thumb button ($X_{diff} \pm .08, p < .05$) by comparison with the

displacement yoke where no significant differences between targets were found (see Figure 9). The analysis also revealed that subjects who used the displacement yoke achieved a higher percentage of hits on evasive targets, than subjects who used the thumb button ($X_{diff} \pm .08$, $p < .05$).

Table 7

Target Tracking: Results of ANCOVA of Percent Hits of the Total Number of Trigger Pulls

	SS	df	MS	F	*p*
Controller	0.06	1	0.06	0.91	.411
Subject within controller	2.17	29	0.07		
Target	0.23	2	0.11	5.50	.001
Target x Controller	0.20	2	0.10	5.00	.003
Target x Subject within controller	0.89	56	0.02		

Covariates

	Coefficients	B (standardized coefficients)	Std error	T	*p*
Vertical acceleration	- 0.0720	- 0.062	0.037	- 2.103	.036
Frequency	- 0.0023	- 0.009	0.009	- 0.242	.808

Means and standard deviations(*) in percent

Controller	Thumb button		Displacement yoke
	92 (14)*		96 (11)*

Target	Stationary	Straight line	Evasive
	95 (11)*	93 (15)*	92 (12)*

Target	Stationary	Straight line	Evasive
Controller (thumb button)	96	91	88
Controller (displacement yoke)	95	95	96

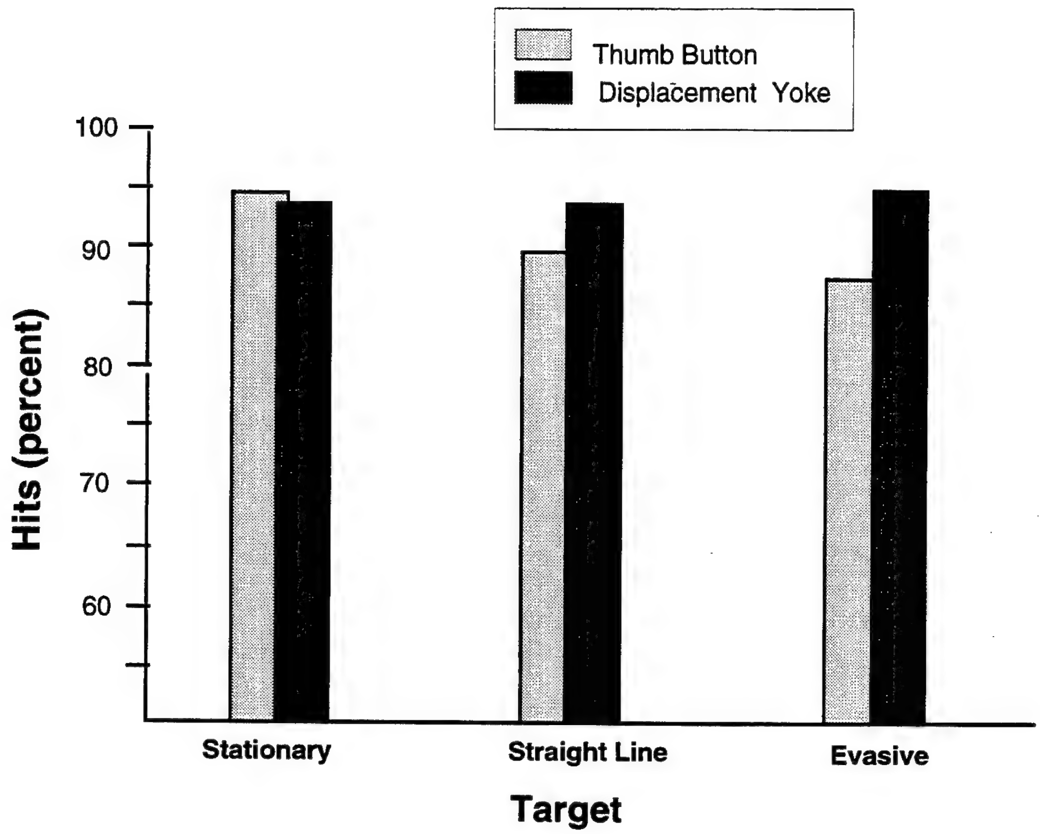


Figure 9. Mean percent hits by target.

A negative relationship (r = -0.072) was found between vertical acceleration and the percent hits of the total number of trigger pulls, t = -2.10, $p < .036$. This finding indicates that as vertical acceleration increased, percent hits decreased. Additional analyses were performed to determine if this relationship between vertical acceleration and performance was consistent for both controls. The results of these analyses indicated that the vertical accelerations imparted to the gunners at Ride Level 4 (see Figure 10) had a greater impact on the percent hits achieved using the thumb button than they did on hits achieved with the displacement yoke ($X_{diff} \pm .096$, $p < .05$).

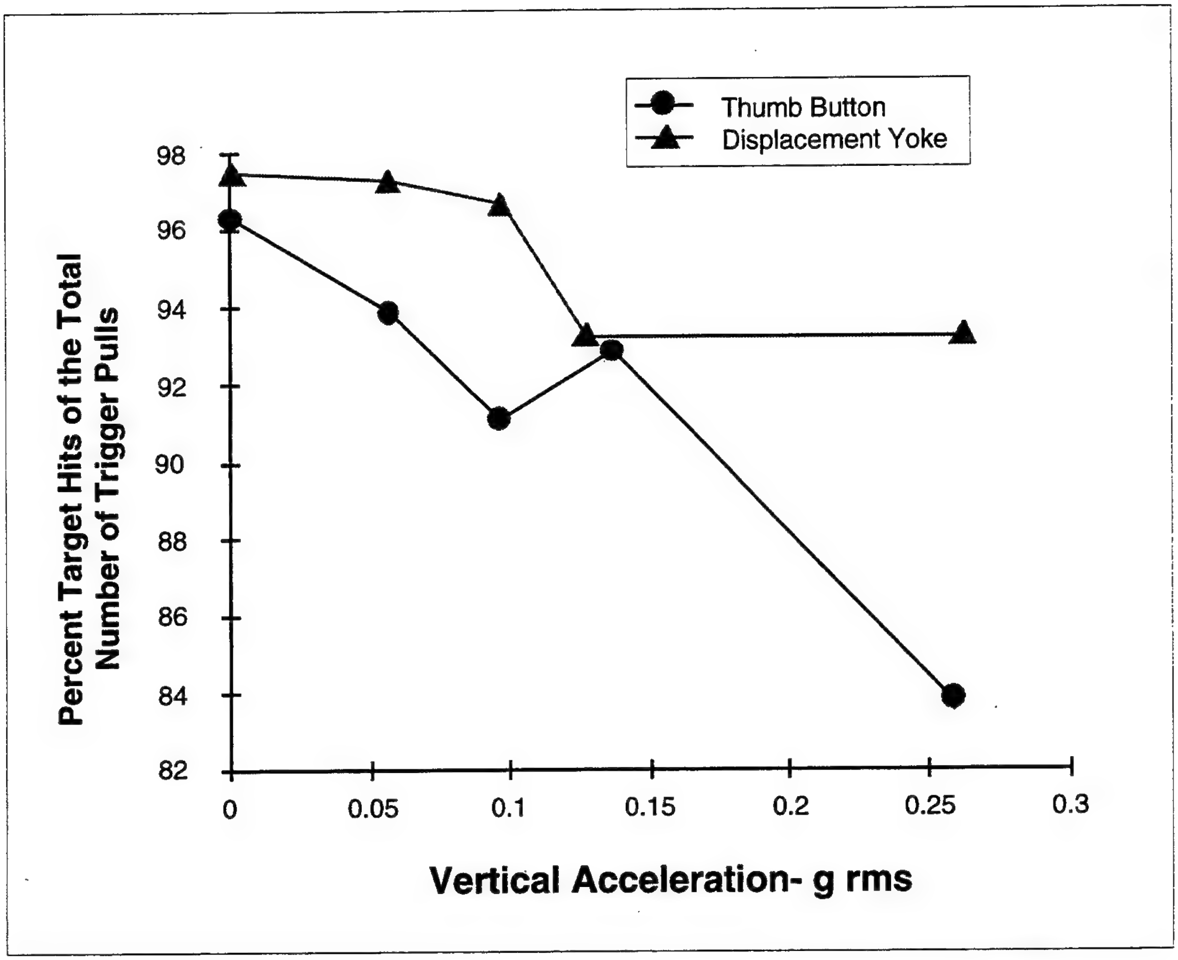


Figure 10. Mean percent hits of the total number of trigger pulls by average vertical acceleration.

Subjective Assessment

Motion Sickness Questionnaire

Comparisons of the subjects' experiences of symptoms before, during, and after training and testing showed no changes in the symptomology that might suggest the onset of motion sickness in either control condition.

Post-Run Questionnaire

The subjects' responses to each of the two questions contained in the Post-Run Questionnaire (see Appendix C) were assigned numerical ratings of 0 ("very difficult") through 4 ("very easy"). For each question and control, the ratings were tabulated across each of the two runs for each ride level. Mean ratings of each of the two controls on each question are provided in Table 8. The results of a chi-square analysis indicated that the ratings of those subjects who

used the thumb button were significantly higher with respect to the ease of target acquisition ($x_1^2 = 29.7$, $p < .05$) and tracking ($x_1^2 = 7.4$, $p < .05$) than the ratings of those subjects who used the displacement yoke. The subjects' ratings were consistent across rides and there was no interaction of ride level and control.

Table 8

Post-Run Questionnaire Results: Mean Ratings of Ease or Difficulty of Target Acquisition (Question 1) and Tracking (Question 2)

Question	Control	Ride level 0	1	2	3	4
1*	Thumb button	3.33	3.40	3.26	3.33	3.00
	Displacement yoke	1.76	2.50	2.43	2.23	2.16
2*	Thumb button	2.83	2.90	2.73	2.76	2.36
	Displacement yoke	2.13	2.53	2.30	2.13	2.03

Rating key: 0 - very difficult; 1 - somewhat difficult; 2 - neither easy nor difficult; 3 - somewhat easy; 4 - very easy
*Significant difference between control ratings ($\rho < .05$)

Post-Test Questionnaire

The subjects' responses to Questions 1 and 2 of the Post-Test Questionnaire (see Appendix D) are provided in Table 9. Responses to Questions 3 and 4 are included in Appendix E.

As can be seen, most of subjects who used the thumb button (93%) and those who used the displacement yoke (80%) indicated that the Nomex gloves did not interfere with their ability to acquire or track targets. One subject in each group noted some interference at times. One subject who used the thumb button commented that the glove should be more flexible between the index finger and the thumb. The subject who used the displacement yoke noted an interference between the trigger finger and the palm switch, which he attributed to the size of the handgrips. Those subjects who were "not sure" commented that they did not have the opportunity to operate the control bare handed or use the other functions on the grips.

In response to Question 2, 60% of those subjects who used the thumb button considered target acquisition and tracking with the thumb button to be “somewhat easier” or “much easier” than the control they normally used for tank gunnery. By comparison, 60% of the subjects who used the displacement yoke believed that target acquisition and tracking with this prototype to be “somewhat more difficult.”

Table 9

Post-Test Questionnaire Results: Questions 1 and 2

Question 1: Did the gloves interfere with your ability to acquire or track targets with the ... (thumb button or displacement yoke)?

	Thumb button		Displacement yoke	
Not al all	14	93%	12	80%
Sometimes	1	7%	1	7%
Not sure			2	13%
Often				
All the time				

Question 2: By comparison to the control you normally use for tank gunnery, how easy or difficult was it to acquire and track targets with the ... (thumb button or displacement yoke)?

	Thumb button		Displacement yoke	
Much easier	4	27%		
Somewhat easier	5	33%	2	13%
No difference	1	7%	4	27%
Somewhat more difficult	1	33%	9	60%
Much more difficult				

DISCUSSION

In the present study, it was hypothesized that the additional body stability offered by the fixed yoke that incorporated the thumb button and the opportunity to trigger from the left handgrip would reduce inadvertent input to this control and thus close the gap in performance found in previous research between it and the more conventional displacement yoke (Lee, West, & Glumm, 1980; Glumm, Singapore, & Lee, 1983).

In accordance with the hypothesis, the analyses did not reveal any statistically significant main effects between the two controls in target acquisition and tracking performance. However, significant interactions were found between target and control where additional analyses revealed that subjects using the thumb button achieved less time on moving targets along with a lower percentage of hits on evasive targets than did subjects using the displacement yoke. Generally, as vertical acceleration increased, performance decreased for both controls, but further analyses revealed that the vertical accelerations at some ride levels effected greater degradations in tracking performance using the thumb button then they did using the displacement yoke. At Ride Level 4, where vertical accelerations averaged 0.25 g, degradations of all measures of tracking performance were greater for the thumb button than they were for the displacement yoke, as were degradations in time on target and lay error at Ride Level 2, where vertical accelerations averaged 0.10 g. However, except for time on target, tracking performance using the thumb button appeared to improve at Ride Level 3, where average vertical accelerations of 0.13 g exceeded those of Ride Level 2. This anomaly is attributed to the predictability of the periodic high accelerations, which depicted the ride imparted to the gunner in the M1 when traveling over the evenly spaced moguls on the Churchville test course. These high accelerations were separated by intervals of relatively low acceleration representative of the smooth terrain between these moguls. Gunners using the thumb button used these mild segments of the ride to their advantage, removing their thumb from the tracking control during moments of high acceleration while maintaining their grip on the fixed yoke for body stability. In reality, during less predictable motion conditions, as vertical acceleration increases, gunner performance using the thumb button is expected to be degraded.

In an earlier study (Lee, West, & Glumm, 1980), degradations in tracking performance using a thumb button on a fixed joystick had been attributed, in part, to inadvertent input to the thumb control when tracking and trigger pull functions were performed by the same hand. In the present study, this problem was made more apparent by the high force required to depress the firing triggers on the fixed yoke that incorporated the force-sensitive thumb button. Those subjects who used the thumb button noted the problem early in training and opted to use the trigger on the opposite handgrip. However, there were a few occasions during testing when it was observed that some of these subjects inadvertently switched, if only for a moment, to triggering with the preferred hand. In contrast to previous research in which subjects wore chemical protective gloves (Glumm, Singapore, & Lee, 1983), there was no evidence to suggest that the more form-fitting Nomex gloves had a significant effect on performance with either of the two prototype controls.

In the present study, 5 of the 15 soldiers who used the thumb button claimed that they applied inadvertent force to the button on severe bumps, causing the reticle to "jump off target." This may suggest that the tightening of one's grasp about the handgrips to maintain body stability had an effect similar to that of tracking and triggering with the same hand.

In their years of experience in the M1 tank, gunners have learned techniques that help them to stabilize their bodies and reduce feed-through of motion to their controls. In this study, some of these techniques could not be applied using the fixed yoke that incorporated the thumb button, partly because of differences in control design and the interface of these controls with the gunner. Some subjects commented that they normally stabilize themselves in the seat of the M1 tank by holding their elbows tight to their sides, but the handgrips of the fixed yoke assessed in this study were too far apart to allow this. The handgrips, some stated, should be canted back to allow a more natural grip. The thumb button was too high on the handgrip, and some subjects observed that their thumbs rested on the lower ridge of the button rather than lying flat on its surface.

Although a number of subjects were pleased at the speed at which they could slew the reticle using the thumb button, some considered the control to be too sensitive. Fine corrections in reticle positioning frequently resulted in overshoot. As target motion became more complex, such corrections were required more frequently, and time on target decreased. Added to this, perhaps, were those corrections needed to compensate for inadvertent input to the thumb button because of the spread of neural excitation to the thumb upon movement of other fingers on the same hand. As time on target decreased so too might the number of trigger pulls and the precent of target hits.

Given the difficulties experienced by subjects using the thumb button, together with the effects of experience and adaptation to the use of a displacement yoke similar to that assessed in this study, one might then have expected significant main effects in performance between the two prototype controls. However, the displacement yoke assessed in this investigation was a prototype. It was not the one used in the M1A1 tank, nor had it been assessed in previous research on the RMS. Many of the soldiers who participated in the present investigation were quick to point out the differences in design between the prototype yoke and the conventional "Cadillac." One of the more frequent complaints was that the handgrips were too short and that there was not enough clearance between the trigger and the palm grips. Some crewmen claimed that the trigger did not conform as well to the finger. They preferred the "easier," shorter stroke of the triggers on the "Cadillac." The subjects' most frequent complaint was that the prototype

displacement yoke was "stiff" in both elevation and azimuth and that small adjustments were difficult. The relatively poor ratings on the ease of acquiring and tracking targets using this prototype yoke most likely reflect a comparison with the subjects' experiences using the "Cadillac" in the M1 tank. It may be surmised from this that the closing of the gap in performance between the two controls assessed may not have been attributable to any improvements that the fixed yoke with thumb button offered over previously tested control configurations but perhaps to shortcomings in the design of the prototype displacement yoke assessed in this study.

CONCLUSIONS AND RECOMMENDATIONS

In this study, no statistically significant main effects were found between the fixed yoke with thumb button and the displacement yoke in either target acquisition or tracking performance. However, in the target tracking task, significant interactions were found between target and control, indicating that target motion had a greater effect on time on target and percent hits using the thumb button than it did using the displacement yoke. Generally, as vertical acceleration increased, target acquisition and tracking performance decreased in both control conditions. However, additional analyses revealed that vertical acceleration also had a greater impact on tracking performance using the thumb button than it did using the displacement yoke, particularly at a ride level where vertical accelerations averaged 0.25 g.

A multitude of factors may have degraded gunner performance in both control conditions and may have influenced the greater effects of target motion and vehicle ride on performance using the thumb button. The comments of the crewmen who participated in this study provide valuable insight as to problems in the design of each of the prototype controls that may have affected these degradations. Some of these problems may have been resolved before this study if the user had been consulted and his requirements addressed in the development of these prototype control handles. Additional insight would also have been gained through measurement and comparison of the transfer functions and spring rates of the prototype yoke assessed in this study with those of the conventional "Cadillac" control.

Future studies assessing the performance of these or other prototype control handles should include a comparison with the baseline "Cadillac" control. Fatigue always poses a potential confound, but if time and money permit, within-subject study designs in which a subject's performance is measured in all control conditions are preferred.

Finally, before any final design decisions are made about any tracking control, whether it be an isometric thumb button or a displacement yoke, the gunner's ability to use the control while wearing other glove configurations (e.g., nuclear-biological-chemical [NBC] and cold weather) should be assessed.

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APPENDIX A

DEMOGRAPHIC QUESTIONNAIRE

DEMOGRAPHIC QUESTIONNAIRE

Please answer the following questions. The information you provide will be kept CONFIDENTIAL.

1. Name: ____
   Last First Middle Initial

2. Age: __________

3. Rank: _________________

4. Military Occupational Specialty (MOS): _______________

5. Time in Service: ______years ________ months

6. Time in grade: _______years ________ months

7. Time in MOS: _______years ________ months

8. Are you left- or right-handed?

   Left-Handed [ ] Right-Handed [ ]

9. Do you wear eyeglasses or contacts?

   Yes [ ] No [ ]

10. How many times have you fired the tank main gun?

0	[ ]
1 - 5	[ ]
6 - 10	[ ]
11 - 20	[ ]
20 or more	[ ]

If you have answered " 0" to Question #10, move on to Question#19.

11. From which crew position did you fire the main gun?

Commander	[ ]
Gunner	[ ]
Both	[ ]

12. When was the last time you fired the main gun?

Less than a week ago	[ ]
Less than a month ago	[ ]
Less than six months ago	[ ]
More than a year ago	[ ]

13. Have you fired the main gun in combat?

Yes [ ] No [ ]

14. Have you done any firing on the move?

Yes [ ] No [ ]

If Yes, how many times have you fired the main gun on the move? ________ times

15. When was the last time you fired Level I gunnery?

________ years? ________ months? ________weeks?

16. Did your crew qualify in the last Level I gunnery?

Yes [ ] No [ ]

17. When was your most recent gunnery training?

________ years? ________ months? ________weeks?

18. Were you a member of the NET team?

Yes [ ] No [ ]

19. How often do you play video or arcade games? *(Check one)*

Everyday	[ ]
1 - 3 times a week	[ ]
1 - 3 times a month	[ ]
1 - 3 times a year	[ ]
Not at All	[ ]

If you answered "Not at All" to Question #19, go to Question #25.

20. Where do you play video or arcade games?

Home	[ ]
Arcade	[ ]
Both	[ ]

21. On the average, when you do play video or arcade games, about how long do you play them?

Less than 2 hours	[ ]
3 - 5 hours	[ ]
6 - 10 hours	[ ]
More than 10 hours	[ ]

22. What video systems do you use? (Check all that apply)

Nintendo	[ ]
Super Nintendo	[ ]
Genesis	[ ]
Sega CD	[ ]
Sega Saturn	[ ]
Jaguar	[ ]
Home Computer	[ ]
Other *(specify)* ________________	

23. For those video systems that you use, do you use the controller that came with that system? *(If "No", please specify)*

	Yes	No
Nintendo	[ ]	[ ] ______________
Super Nintendo	[ ]	[ ] ______________
Genesis	[ ]	[ ] ______________
Sega CD	[ ]	[ ] ______________
Sega Saturn	[ ]	[ ] ______________
Jaguar	[ ]	[ ] ______________
Home Computer	[ ]	[ ] ______________
Other	[ ]	[ ] ______________

24. How old were you when you started playing video or arcade games? __________years

25. Have you ever been motion sick (for example: seasick, carsick, airsick, trainsick, etc.) ?

Yes [ ] No [ ]

If YES, explain. ____

____

____

26. Have you ever been motion sick in a tank?

Yes [ ] No [ ]

If YES, explain. ____

____

____

27. How susceptible are you to motion sickness?

Extremely	[ ]
Very	[ ]
Moderately	[ ]
Minimally	[ ]
Not at All	[ ]

APPENDIX B

MOTION SICKNESS QUESTIONNAIRE

Name: ______________
Training Run #: __________
Testing Run #: __________

Motion Sickness Questionnaire

INSTRUCTIONS: For each item listed, place an " X " in the box to correspond to **HOW YOU FEEL AT THIS MOMENT.** PLEASE ANSWER EVERY ITEM.

		Not at All	Slight	Somewhat	Moderate	Quite a Bit	Extreme	
1	Generally uncomfortable	☐	☐	☐	☐	☐	☐	14
2	Tired	☐	☐	☐	☐	☐	☐	15
3	Depressed	☐	☐	☐	☐	☐	☐	16
4	Sleepy	☐	☐	☐	☐	☐	☐	17
5	Headache	☐	☐	☐	☐	☐	☐	18
6	Dizzy (with eyes closed)	☐	☐	☐	☐	☐	☐	19
7	Dizzy (with eyes open)	☐	☐	☐	☐	☐	☐	20
8	Disoriented	☐	☐	☐	☐	☐	☐	21
9	Sweaty	☐	☐	☐	☐	☐	☐	22
10	Faint	☐	☐	☐	☐	☐	☐	
11	Aware of my breathing	☐	☐	☐	☐	☐	☐	
12	Nauseous (Sick to stomach)	☐	☐	☐	☐	☐	☐	
13	Burping	☐	☐	☐	☐	☐	☐	

1

#:	
:	

Bit	Extreme
	☐
	☐
	☐
	☐
	☐
	☐
	☐
	☐
	☐
	☐
	☐
	☐
	☐

		Not at All	Slight	Somewhat	Moderate	Quite a Bit	Extreme
14	Hungry	☐	☐	☐	☐	☐	☐
15	No appetite	☐	☐	☐	☐	☐	☐
16	Chills	☐	☐	☐	☐	☐	☐
17	Blurred vision	☐	☐	☐	☐	☐	☐
18	Decreased salivation (dry mouth)	☐	☐	☐	☐	☐	☐
19	Increased salivation	☐	☐	☐	☐	☐	☐
20	Hot flashes	☐	☐	☐	☐	☐	☐
21	Clammy	☐	☐	☐	☐	☐	☐
22	Vomiting		YES ☐		NO ☐		

Thank you

2

APPENDIX C

POST-RUN QUESTIONNAIRES

POST-RUN QUESTIONNAIRE

Run #: ________

Name: ______________________________ Date: _____________

Based on your experience using the control ***during this past run,*** *please answer each of the following questions by placing an "X" in the appropriate box. Space is also provided after each question for any comments you might have.*

1. How easy or difficult was it to slew quickly and accurately on target with the thumb control?

Very Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Very Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

2. How easy or difficult was it to maintain your crosshairs on target with the thumb control?

Very Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Very Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

Run #: ________

POST-RUN QUESTIONNAIRE

Name: ______________________________ Date: ____________

Based on your experience using the control ***during this past run,*** *please answer each of the following questions by placing an "X" in the appropriate box. Space is also provided after each question for any comments you might have.*

1. How easy or difficult was it to slew quickly and accurately on target with the displacement yoke control?

Very Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Very Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:
____
____
____

2. How easy or difficult was it to maintain your crosshairs on target with the displacement yoke control?

Very Easy	Somewhat Easy	Neither Easy nor Difficult	Somewhat Difficult	Very Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:
____
____
____

APPENDIX D

POST-TEST QUESTIONNAIRES

POST-TEST QUESTIONNAIRE

Name: ______________________________ Date: ____________

Please answer each of the following questions by placing an "X" in the appropriate box. Space is also provided after each question for any comments you might have.

1. Did the gloves interfere with your ability to acquire or track targets with the thumb control?

Not at All	Sometimes	Not Sure	Often	All the Time
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

2. By comparison to the control you normally use for tank gunnery, how easy or difficult was it to acquire and track targets with the thumb control?

Much Easier	Somewhat Easier	No Difference	Somewhat More Difficult	Much More Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

3. Is there something that you would change about the control that you used during this study that would improve your ability to acquire and track targets?

____

____

4. Is there something that you would change about the Nomex gloves that would improve your ability to acquire and track targets?

____

____

POST-TEST QUESTIONNAIRE

Name: ______________________________ Date: ____________

Please answer each of the following questions by placing an "X" in the appropriate box. Space is also provided after each question for any comments you might have.

1. Did the gloves interfere with your ability to acquire or track targets with the displacement yoke control?

Not at All	Sometimes	Not Sure	Often	All the Time
[ ]	[ ]	[ ]	[ ]	[ ]

Comment:

____

____

____

2. By comparison to the control you normally use for tank gunnery, how easy or difficult was it to acquire and track targets with the displacement yoke control?

Much Easier	Somewhat Easier	No Difference	Somewhat More Difficult	Much More Difficult
[ ]	[ ]	[ ]	[ ]	[ ]

3. Is there something that you would change about the control that you used during this study that would improve your ability to acquire and track targets?

____

____

4. Is there something that you would change about the Nomex gloves that would improve your ability to acquire and track targets?

____

____

APPENDIX E

POST-RUN AND POST-TEST QUESTIONNAIRES: SUBJECTIVE COMMENTS

POST-RUN AND POST-TEST (*) QUESTIONNAIRE: SUBJECTIVE COMMENTS

SUBJECTIVE COMMENTS*

The following are a compilation of the subjects written comments provided in both the Post-Run and Post-Test Questionnaires. Those comments marked with an asterisk (*) are those specific to the Post-Test Questionnaire.

Fixed Yoke with Thumb Button

Cursor seems extremely sensitive...trigger is very stiff. Cursor difficult to maintain on evasive target.

Over-sensitive thumb switch.

Thumb control sensitive ...over slew.

Moving target more difficult than stationary.

Hard to maintain crosshairs on bumps.

Difficult to maintain crosshairs on target, especially on moving and evasive targets.

Difficult to use and maintain target-reticle relationship.

Occasional bounces cause my thumb to move reticle off target. Able to quickly correct. Terrain driving made it harder to maintain reticle on targets. Again bouncing moves my thumb. Rotating handle top back would allow me to support my hand with my knee.

Noticed that you must, while tracking, release the tracking button for rough terrain for a split second.

The severe bumps cause reticle to jump off target due to the moving of the thumb.

Slewing became easier with practice.

Fine adjustments are difficult, but only require practice.

Used only left hand trigger.

Gets tough when you hit bumps.

I feel that the thumb tracking will just take getting used to. Tracking and firing with the same hand to be a little more difficult.

Very unique system...once mastered will cut down engagement times by at least 15 - 20%.

Hard to track when bouncing. Thumb slips when vehicle bounces.

Thumb switch needs to be lowered 1-1.5 inches to reduce strain on thumb.

Task might be easier if yoke was closer in so I could lock elbows into my side.

Change angle so hand set very natural.

Handgrips should be canted back to allow a more natural grip.

...all together would take time to learn all the new knobs and what they are used for.

Change right hand position to allow thumb straight-down on button instead of thumb laying down and pushing button from bottom.

Trigger should extend further out from the handgrip to accommodate the longer stroke.

Trigger has a sharp point and should be reshaped.

Trigger should not have the hard torque that it does. It should just have that smooth cylinder click like the older models.

* Make cursor control less sensitive...loosen up trigger.

* Make thumb control more contoured to fit around side of thumb.

* Make the triggers not so hard to engage.

* Change the angle of the yoke, loosen trigger.

* Change the location of the thumb switch.

* Thumb control needs to be bigger.

<u>Displacement Yoke</u>

Difficult to track vertically and horizontally at the same time.

Hydraulics (real tank) are more responsive and predictable.

Elevation...up and down...stiff.

The controls are much more stiff than on a U-COFT or actual M-1 tank.

Good design but small adjustments are hard to make.

Learning the peculiarities of hand control responsiveness.

Still feeling the stiffness of the controls.

I think I may be getting more acquainted with the controls.

The jarring around is greatly affecting the movements of the reticle.

Getting easier... probably getting accustomed to the equipment.

The ride almost increased my ability to slew the reticle or maybe it was knowing it was the last iteration.

Smooth.

Slow on fine tuning.

Small corrections seem difficult.

Tension causes fatigue in wrist rather quickly.

When moving the fine adjustments are hard to make.

Crosshairs move off target during a sharp move up or down.

* When jumping around its hard to track...stationary is no problem.

* Make a control that allows smaller corrections - smoother, more accurate.

* Electric versus hydraulic...hydraulic easier (track only).

* Smooth motion, but final movements are erratic.

* Make more sensitive and responsive to minor correction.

* Reduce centering friction, raise sensitivity at near-center tracking.

* Allows alot of dexterity and flexibility.

* Increase palm length.

* With the smaller grips on the control the trigger finger will rub and cause some drag when pulling the trigger.

* Trigger needs to be further away from the palm switches.

* Lengthen the control handles, enlarge finger grips, move triggers.

* Trigger needs to be redesigned to better fit the trigger finger.

* There's only one laser button on yoke.

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13. ABSTRACT *(Maximum 200 words)*

This report describes a study designed to quantify the effects of vehicular induced motion on tank gunner performance using two different control handles. One control was a fixed yoke that incorporated a thumb-operated tracking button. The second control was a more conventional displacement yoke which functioned like that in the current M1A1 tank. The study was conducted on a ride motion simulator which had been programmed to impart four levels of ride motion. These ride levels were derived from a simulation of the M1 tank traveling over various test courses at Aberdeen Proving Ground, Maryland. Generally, as vertical acceleration increased, performance decreased for both controls, but the vertical accelerations imparted to the gunners at the more severe ride levels effected a greater reduction in time on target using the thumb button than they did when using the displacement yoke. Performance using the thumb button was more affected by target motion.

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